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GRAPHITE

PART II -DOMESTIC AND FOREIGN DEPOSITS

BY

PAUL M. TYLER

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DEPARTMENT OF COMMERCE - BUREAU OF MINES

G R A P H I T E

PART II. DOMESTIC AND FOREIGN DEPOSITS[1]

By Paul M. Tyler[2]

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FOREWORD

Graphite occurs in many places in the United States, but previous to 1914 the domestic production amounted to only 15 to 20 per cent of the natural graphite consumed in this country. Including artificial graphite, the proportion was about 25 per cent. During the World War the production of both natural and artificial graphite increased until in 1918 it contributed more than one-half of the available supply, and since 1919 the proportion has not fallen below 40 per cent. Except during the war period, however, this apparently increasing independence has not been due to any large increase in production from domestic mines. It simply reflects a larger output of artificial graphite and reduced imports of Ceylon lump and chip, grades which have never been produced in substantial quantity in the United States.

DOMESTIC DEPOSITS[3]

American graphite deposits, though numerous and often large, are characteristically low-grade. They constitute an abundant source of potential supply, but in normal times they have proved relatively costly to work, and even at the same price the various products have never been able wholly to displace certain imported qualities, notably crucible grades from Ceylon and pencil graphite from Mexico.

Marked changes in the nature of consumption have reduced the demand for crucible grades of graphite, so that differences in quality between the domestic and foreign supplies tend now to be of less significance than formerly. These changes likewise have increased the proportion of the total consumption that can be satisfied by artificial graphite whose range of usefulness includes many of the applications of crystalline as well as of amorphous grades. Since there is normally a surplus of petroleum coke and an ample supply of anthracite coal, the production of artificial graphite could doubtless be expanded readily if necessary -- probably much faster than the output of crystalline graphite, all of which has to be concentrated. In Alabama and elsewhere, however, there are many idle mills that could probably be started again, rather promptly. The principal known deposits of crystalline flake graphite in the United States are in Alabama, California, New Jersey, New York, Pennsylvania, Texas, and Virginia. Other localities include Alaska, Colorado, and North Carolina. In Montana is the only known domestic deposit of vein graphite. Amorphous graphite is found more or less abundantly in Colorado, Michigan, Nevada, Rhode Island, New Mexico, and Wisconsin, and there are great beds of graphitic schists of possible commercial significance in Maine and in South Dakota, Wyoming, and certain other western States.

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3 - The data herein given with respect to domestic deposits have been taken mainly from Mineral Resources chapters prepared by Bastin, Ferguson, and Middleton, or from other published sources, and are supplemented by a very limited amount of field work by the writer.

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Alabama[4] - Moderate-sized flake graphite, rather smaller than that produced in certain other localities, occurs in Alabama in bands of graphitic schist in Clay, Coosa, and Chilton Counties in the vicinities of Ashland, Mountain Creek, and Good Water, respectively. The schist usually dips steeply to the southeast and, associated with granitic intrusions, occurs in lenses up to 100 feet wide in metamorphic rocks, usually pre-Cambrian schists similar to the ore itself but containing more mica. According to Dr. W. B. Jones, Alabama State Geologist, graphite outcroppings are found in four counties in 16 different beds, of which 13 are of commercial importance. He considers the supply limitless.[5] The rock is largely quartz with some mica and apatite, and with rarely more than 3 or 4 per cent of graphite. The average war-time yield per ton mined was about 19 pounds of No. 1 flake, 5 pounds of No. 2 flake, and 3 pounds of dust -- a recovery of a trifle more than 50 per cent of the total graphite, which averaged about 2½ per cent in the rock as mined. Subsequently, more efficient milling has made possible a 75 per cent recovery from rock containing only 2 per cent of graphite, the yield per ton being about 14 pounds of No. 1, 4 pounds of No. 2, and 7 pounds of dust (mainly No. 3 dust containing 75 to 85 per cent carbon). Usually a small amount of overburden (1 to 6 feet) has to be removed, and mining is stopped at 30 to 60 feet where hard, unweathered "blue rock" is reached. The deposits are worked opencast, and few mines are as much as 75 feet deep. The weathered ore can be mined largely by hand picks and is much easier to mill than the hard ore. The latter, moreover, contains a small amount of pyrite, which is not present in the weathered horizons of the ore bodies. Amorphous graphite is also found in Alabama in the feebly crystalline schists or the Talladega slates,[6] as a black graphitic clay free from grit. Occurrences of this sort have been observed near Millerville in Clay County and in the vicinity of Blue Hill in Tallapoosa County, but such material is difficult to separate and has not yet been worked commercially to any great extent.

Graphite mining in Alabama was attempted as early as 1888 and was established in a small way in 1900. The chief development of graphite in Alabama, however, occurred during 1917 and 1918, when for a time there were 39 concentrating mills in the area, over one-half of which were in actual operation. Activity continued after the Armistice until later in 1920, when the industry collapsed, remaining almost at a standstill until 1926. In 1927 three operators reported sales of 3,474,000 pounds of crystalline graphite, or two-thirds of the total for the United States. Though only a little less than one-half the record sales made in 1918, the 1927 output was more than double the annual production in pre-war years.

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4 - Prouty, W. F., "Geology and mineral resources of Clay County": Rept. No. 1, Geol. Survey of Alabama, 1923. Brown, John S., "Graphite deposits of Ashland, Alabama": Econ. Geol., vol. 20, No. 3, May, 1925.

5 - Statement before Ways and Means Committee, Tariff Readjustment Hearings, 1929.

6 - McCalley, H., Alabama Geol. Survey Rept. Valley Regions, pt. 2, 1897, pp. 36-38.

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In 1927 the producing companies were the Bama Graphite Mines, successor to the Flaketown Graphite Co., The Superior Flake Graphite Co., and the Southwestern Consolidated Graphite Co. which has been operating for a number of years in Texas and recently took over and operated the plant of the Ceylon Co. at Hollins, Ala. The Alabama-Quenelda Graphite Co., successor to the Quenelda Graphite Corporation, expects to operate during 1928. According to Bastin,[7] the quarry and mill of the Quenelda Co. were located a little over eight miles west of Ashland, to which the concentrate is hauled for shipment. The rock mined is highly schistose, and is composed largely of quartz and graphite. Feldspar and mica are rare, but a white fibrous mineral (probably sillimanite) is abundant. The original mill which combined wet and dry concentration was destroyed by fire. The property of the Flaketown Graphite Co. is in Chilton County, about 3½ miles northeast of Mountain Creek (the nearest shipping point). The rock is a graphitic quartz schist of the same general type as those mined in the vicinity of Ashland. Small quantities of green micaceous mineral, probably muscovite, are present in some specimens, but in general mica is rare. A dike of granite pegmatite 1 foot wide intrudes the graphitic schist at the main pit, lying parallel to the foliation. Within 1 or 2 inches of the schist it carries graphite in scattered flakes up to 1/8-inch in diameter. An analysis made by the United States Geological Survey of a composite sample of graphitic schist collected from a number of different exposures of this property, showed 4.63 per cent of graphite. During part of the year electric power for the mill is generated by water power from a 24-foot dam on Chestnut Creek. Auxiliary steam power has also been installed.

Alaska - Crystalline graphite was produced intermittently in Alaska from 1905 until 1918. Most of the output was in the nature of trial shipments, chiefly to experimental mills in the State of Washington, although a little of it was manufactured into foundry facings in San Francisco. The deposits which occur on the northern and southern slopes of the Kigluaik Mountains, in the southern part of Seward Peninsula, have been visited by geologists of the United States Geological Survey. The lenses of graphite occur in association with quartz schists carrying biotite, and garnet schists carrying some calcite. Granitic rocks are found nearby. Locally there are two or three series of graphite lenses which are parallel in strike and dip. It is not known whether these are distinct horizons, or merely result from faulting or folding. There are a number of exposures showing lenses varying in thickness from one foot to several feet, and it is reported that these deposits of graphite offer an opportunity for large production. Transportation problems are simple, as the ore could be carried to Graphite Bay, a good shallow-water harbor.[8]

Arkansas - In Arkansas graphite has been reported in the western part of Pulaski County and also in Crawford County. Some development was in progress in Crawford County in 1910 on material said to run 40 to 60 per cent in carbon, but Bastin, who examined the prospects in 1912, reports that the deposit was

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7 - U. S. Geological Survey, Mineral Resources of the United States, 1913: Pt. 2, pp. 191-193.

8 - U. S. Bureau of Mines, Mineral Resources of the United States, 1917: Pt. 2, pp. 113-115.

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not graphite but was a thin bed of carbonaceous shale.

California - California resumed production in 1927 after a lapse of four years. The Standard Graphite Corporation revived a property which, though worked intermittently for 30 years, seemed incapable of commercial production before the flotation process was introduced. The ore is crystalline graphite occurring in small flakes finely disseminated through schists which are locally enriched up to a thickness of 100 feet, and contain lenses of high-grade ore varying in width from 6 inches to 15 feet. Mining is conducted by means of shallow tunnels and open-cuts.[9]

This mine is situated about 15 miles north of Los Angeles, and is characteristic of other deposits in Los Angeles and San Diego Counties, all of which resemble in a general way characteristic occurrences in New York, Pennsylvania, and Alabama. The California flake, however, is much smaller than that found in many of the eastern deposits, often being only 0.25 millimeter in diameter. The percentage of graphite, however, is higher, and due to the fact that mica is practically absent, it is fairly easy to concentrate by modern methods into a product suitable for foundry facings and paints. Probably products even purer could be made if necessary, but the smallness of the flake makes it of little value for crucibles or refractories, although it is probably suitable for lubricating stock. Before the World War some graphite was mined in Calaveras and Mendocino Counties.

Colorado - Amorphous graphite was produced fairly steadily in Colorado before 1922. A considerable portion of the output was sent to a mill at Warren, Ohio, where it was prepared for use in paints, foundry facings, etc. The deposits appear to be related in origin with the Cretaceous coal deposits of the Crested Butte area. Anthracite coal has also been found nearby. In addition to the main bed, there are a number of subordinate beds, interbedded with white to gray crystalline limestone, buff quartzite, and gray to purple silicious schists. A dike of fine-grained granite cuts the sediments a few feet from the main graphite bed, which varies in thickness from 3 to 4 feet, and about one-half of which has been second-grade ore containing more clay and less graphite than the first-grade ore, which is dull black and very pure. The first-grade graphite used to be packed in bags, while second-grade was shipped in bulk. The property of the Federal Graphite Co., the principal producer, was situated northeast of Turret in Chaffee County, 5 miles from a siding of the Denver & Rio Grande Railroad. Since 1916 graphite has been produced in some quantity in Gunnison County, near Pitkin, about 10 miles from the railroad.

Georgia - Georgia has produced no true graphite, but a large quantity of slate containing 2 to 15 per cent carbon quarried near Cartersville in Bartow County has been ground for use as a filler and dryer in fertilizers. For some years prior to 1910, the output of this material was included in the production statistics, but since it is not adapted for any of the purposes for which higher grades of amorphous graphite are used and since these higher grades are not used

9 - Hubler, W. G., "Concentrating graphite in southern California": Eng. and Min. Jour., vol. 125, June 30, 1928, p. 1059.

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as fertilizer filler, this material is no longer classed as graphite. It formerly sold at $1.25 to $1.50 a short ton f.o.b. mills. The deposits have been described by Hayes and Phalen.[10]

Idaho - In 1908 a graphite mine was opened in Ketchum, Blaine County, Idaho, and a little amorphous graphite was reported to have been produced in the following year. Graphitic schists occur near Salmon River, near Grangeville; a specimen analyzed by the United States Geological Survey in 1912 contained 7.67% fixed carbon.

Maine - Graphite is known to occur in several localities in Maine, and in 1905 an unsuccessful attempt was made to mine it near Madrid in Franklin County. According to George Otis Smith[11] graphite occurs at Madrid in very small particles, ranging from 0.5 to 0.20 millimeters in diameter, fairly evenly distributed in a schist near its contact with granite pegmatite. A sample analyzed 8.5 per cent graphite, but it would be extremely difficult to prepare a marketable product because the graphite, in addition to being so small, is intimately associated with mica flakes (muscovite). In Cumberland County, 1½ miles northwest of Yarmouth, graphite occurs as disseminated flake in a dike of granite pegmatite. The sample analyzed 9 per cent graphite by weight, but as the dike is only 1 foot wide, the deposit is not considered to have any immediate value.

Massachusetts - Considerable historical interest attaches to a graphite deposit near Sturbridge between Worcester and Springfield in Massachusetts. This mine was not only the first graphite mine worked in the United States, but was one of the first mining ventures of any kind in America. It was first secured by a grant to John Winthrop, jr. (son of Governor Winthrop of Massachusetts), who also purchased the tract from the Indian inhabitants between 1644 and 1658. The preliminary operation appears not to have been successful, but in 1738 mining was resumed, and one or more shipments were made to England, where the material brought about 4 pence a pound. Less than 1 ton was extracted in the summer of 1740, and there is no record of further development until 1828-29, when it was operated by Frederic Tudor of Boston as an adjunct to the manufacture of crucibles.[12] After again being idle for many decades it was eventually sold in 1902, after which it was operated intermittently for a few years. One lump of solid graphite weighing 510 pounds was reported to have been taken out in 1904.

The graphite from this mine apparently was similar to the occurrences in Ceylon and at Dillon, Mont., but apparently it formed a series of disconnected lenses or flat pockets, mostly less than 3 or 4 inches thick, conformable with the bedding but not very persistent. The containing rock was quartzose mica schist intruded by small masses of granitic rock. The main lode has been prospected to a depth of 50 to 60 feet for a half mile or more, and the chances of further production are not favorable.

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10 - Hayes, G. H., and Phalen, W. C., Graphite deposits near Cartersville, Georgia: U. S. Geol. Survey Bull. 340, 1908, pp. 463-5.

11 - Smith, G. O., Graphite in Maine: U. S. Geol. Survey Bull. 283, 1906, pp. 480-483.

12 - Hayes,, G.H., "The tale of Tantiusques, an early mining venture in Massachusetts": Am. Anti. Soc. Proc., Ann. Mtg., Oct. 31, 1901. (Reviewed in Mineral Resources, 1913.)

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Michigan - Graphitic slate, classed as amorphous graphite, has been produced in considerable quantities near L'Anse in Baraga County, Mich. The rock mined is a dark reddish-brown graphitic and ferruginous material said to average 33 to 35 per cent of graphitic carbon. After careful sorting it is crushed, ground, air-floated, and bolted through 200-mesh silk. It has been used for paint pigment, and has been employed in the manufacture not only of black paints but, mixed with other pigments, also of gray, dark-green, and dark-red paints.

Montana - The only graphite property operated in Montana is that of the Crystal Graphite Co., near Dillon. This deposit yields vein graphite very similar to Ceylon material. The rocks immediately associated with the graphite deposits are (Paleozoic?) limestones and quartzites, which lie above schists and slates that are probably pre-Cambrian. The sedimentary formations are intruded by granite and pegmatite. There are several graphite veins, the main vein showing from 2 to 8 inches of very pure graphite. In one of the exposures the vein is 2 feet wide and consists of an irregular network of graphite veinlets enclosing the many shattered fragments of schist graphite forming about one-half the vein material. According to Bastin,[13] the graphite of this mine is in the form of rather irregular veins deposited along fracture planes and more or less broken by later fracturing. Particularly near the surface, thin films of iron oxide often occur along parting planes between the graphite plates. The graphite is a little softer than that from Ceylon and grinds up more easily, but its lustre is not quite so brilliant. These differences may be due to the fact that the workings are still confined to rather shallow depths. Truly fibrous varieties such as the needle lump, which occasionally occurs in Ceylon, have also been noted in Dillon. Substantial quantities of graphite were produced from this mine during the war period and shipped to eastern consuming centers, but since 1918 the output has been very irregular. In 1927 the company was active mainly in perfecting a milling process.

Deposits of flake graphite in Montana were prospected in 1918, but the profitable operation of such deposits so far distant from consuming centers will prove difficult.

Nevada - The Carson Black Lead Co. has produced amorphous graphite quite steadily for more than 20 years from its property in Ormsby County, 3 miles from Carson City. The material, a black graphitic shale, is said to carry 30 to 50 per cent of graphite; a composite sample from 20 different places across the main pit when analyzed by the United States Geological Survey showed 49 per cent carbon. Separation of the graphite from its associated minerals is not economically feasible, but the shale after fine grinding is suitable for use as paint pigment and as foundry facings. Most of the production to date has been used for the manufacture of graphite paints in a small mill at Carson City operated periodically by the company. The deposit appears to be moderately large, as the shale is traceable for half a mile along the strike and, in places at least, is 100 feet wide. The graphitization may be due to the intrusion of pegmatite granite, which cuts the shale. Other deposits of amorphous graphite have been

13 - U. S. Geological Survey, Mineral Resources of the United States, 1913: Pt. 2, pp. 202-4.

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reported in Nevada, but apparently none of them have been commercially productive. A specimen sent to the United States Geological Survey from Ludwig, Lyon County, was of good quality, and was said to have come from a deposit 4 or 5 feet thick which was visible for several hundred feet along the surface.[14]

New Jersey - Graphite occurs as disseminated flake in the crystalline rocks of the highlands of New Jersey at a number of localities. According to Bayley and Stewart[15] the graphite occurs in several ways: (1) As a component of Franklin limestone; (2) in gneisses which may be in part altered sediments but in places are mashed pegmatites; (3) in coarse granite dikes and pegmatites; and (4) in fine-grained quartzitic micaceous schists, especially where they are associated with pegmatites. The last-named mode of occurrence is the most important. Pegmatites are only graphitized close to the schists, or where they carry fragments of schist.

The latest development is at Annandale where a large quantity of graphitic schist has been opened up. In an open-cut at the bottom of a hill this schist, some of it heavily charged with graphite, has been exposed for a length of 200 feet, roughly, and to a depth of 50 to 75 feet in places. The strata in this vicinity are highly contorted and the workings follow the axis of a well-developed anticline. Tongues of feldspathic rock intrude the schist and in places the schist itself contains bands and small stringers of feldspar, suggesting the presence nearby of pegmatites. Beyond this cut the ground rises abruptly and graphite has been found in drill holes, test pits, and open-cuts at various places beneath the wash (mostly from 3 to 10 feet deep) over an area several thousand feet long and probably a thousand feet wide. A quarter of a mile or more from the lower workings, in the side of what is known as Graphite Hill, a small tonnage of milling ore averaging from 7 to 9 per cent carbon was mined in 1928 by means of a power-shovel, and in this excavation samples of schist found at a depth of 15 feet were said to assay 34½ per cent carbon.

Owing to lack of information as to the thickness of the deposit, it is not possible to make estimates as to the tonnage available, but the development records indicate that possibly millions of tons are within easy reach by surface mining. Moreover, the average grade of the ore seems to be as high as or higher than that of other known deposits in New Jersey where the graphite content has usually been reported as being between 4 to 8 per cent, with occasional samples showing as much as 11 per cent.

Because of their nearness to consuming markets and their moderately high-carbon content the New Jersey graphite deposits have repeatedly attracted the attention of investors, and numerous attempts have been made at various times to utilize the deposits commercially. Concentrating works were erected at Bloomingdale, High Bridge, and near Brookside; all these ventures failed, however,

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14 - Bastin, E. C., Mineral Resources of the United States, 1913: Pt. 2, p. 204.

15 - Bayley, W. S., and Stewart, C. A., "Note on the occurrence of graphite schist in Tuxedo Park, N. Y.": Econ. Geol., vol. 3, 1908, pp. 535-538.

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and no further attempts were made from 1907 to 1925. From the description of the deposits it would seem that the earlier difficulties may have been due in part to the intergrowth of biotite mica and possibly of pyrite (both of which are present in some deposits) and in part to the tendency of the flake to be destroyed by the sharp quartz grains in the process of grinding. "Pancaking" also may have been a factor. In 1925 the Annandale Graphite Co., after some preliminary exploratory work on previously known deposits, discovered and began the development of a new ore body situated along the tracks of the Central Railroad Co. of New Jersey, 55 miles from New York and practically on the concrete highway between New York and eastern Pennsylvania. In February, 1927, a large mill using the dry process was completed, but it failed to produce a concentrate containing more than 32 to 38 per cent carbon. After several months of experimental work a section of this mill was remodeled and run for three months as a pilot plant, producing a concentrate said to average day after day practically 97 per cent of graphite. Extraction was reported as over 90 per cent, and the tailings averaged only one-half per cent carbon. The new process involves graded crushing, first in jaw crushers and rolls and then in rod mills with intermediate screens or classifiers at each stage to remove both the clay and the flake graphite as soon as they are liberated from the rock. The overflow from the various classifiers (all minus 65-mesh) is then treated in K-and-K flotation machines, the froth from which is reground in a rod mill before passing to the K-and-K machines used as cleaners. The cleaned concentrate is pumped to a thickener, then to a vacuum filter, and is finally dried ready for shipment. The concentrate as thus prepared may run over 97 per cent graphitic carbon, but a further cleaning process has been devised for increasing the carbon content to over 99 per cent in graphite for lubricating purposes. A product known as "Lubricite" is being put up in packages for sale to automobile owners and preparations are being made for the marketing of various other specialties, utilizing both large and small flake. The tailings from the ore mined in certain parts of the deposit consist of clean sharp sand, sufficiently high in silica to be sold to manufacturers of refractories. In other portions of the deposit, particularly where the rock has not been weathered, the feldspar content is so high that the tailings could be used only for concrete, road building, etc.

New Mexico - Small quantities of amorphous graphite have been mined in the past from a large deposit that occurs in the canyon of the Canadian River about 7 miles southwest of Raton, in Colfax County, N. Mex. The bed, which lies practically horizontal, has been prospected for a distance of several miles along the outcrop and laterally into the principal coal bed of the Raton field which contains bituminous coking coal. In many places where igneous material has been forced into the coal measures, coke has been formed, but in the Canadian canyon the intrusive mass took the form of numerous sills above, below, and in the coal bed, with the result that coal was completely graphitized, especially where the bed was fractured and the diabase was forced into it. The graphite occurs in pockets in the diabase and is more or less columnar. A representative sample taken where the bed was about three feet thick showed fixed carbon, 76.11 per cent; volatile matter, 6.07 per cent; ash, 16.51 per cent; and moisture, 1.31 per cent. In 1889 some 250 tons of this graphite was shipped to Pennsylvania where it was found suitable for the manufacture of paint; the refined product contained 80 per cent of carbon, the remainder being mostly silicon. The mill

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was being taken apart for shipment to Raton when it was destroyed by fire. Nothing has since been done toward developing this graphite.[16]

New York - For many years New York produced more graphite than any other State. The deposits, which are situated in the foothills of the Adirondacks, mainly in Essex, Warren, Washington, and Saratoga Counties, were worked before the Civil War. The largest graphite mine in the United States was at Graphite, near Lake George and 11 miles south of Ticonderoga. This mine (which was operated by the American Graphite Co., a subsidiary of the Joseph Dixon Crucible Co. of Jersey City, N. J.) was closed in 1921, and several other mines in the vicinity are reputed to be worked out or abandoned as unworkable; nevertheless, the resources of the State are by no means exhausted.

The ore contains on the average about 5 or 6 per cent graphite. While the carbon content is thus more than double the average for Alabama, the ore is unweathered and hard, resembling in this respect the deeper portions of the Alabama deposits, which portions ("blue rock") are not mined. Two classes of deposits have been observed -- one comprising contact metamorphic deposits in limestone, adjacent to pegmatite, and another occurring as regional metamorphic deposits, not far from the contact of the Hague garnet-sillimanite gneiss with the Faxon limestone or Swede Pond gneiss. The former class, although it contains large flakes of graphite, has proved too erratic and pockety for profitable development. The regional metamorphic deposits on the other hand have proved quite regular and uniform. The ore beds range in thickness from 10 to 25 feet, averaging possibly 15 feet. They dip 25 to 35°, so that as mining progresses, open-pit mining rapidly gives way to underground operations employing ordinarily the room-and-pillar system with underhand stoping. Power drills have been used at most mines, as the rock is hard.

The graphite deposits of New York, including prospects and abandoned mines as well as those which were operated during the war, are described in great detail in a report by H. L. Alling[17] who distinguishes the deposits of the northern area, mainly limestone contact deposits, from those of the southern area which are characteristically bedded. On the map the line runs only a trifle north of Lake George and considerably to the south of Lake Champlain. The northern area includes the deposits of Essex County and sundry prospects and abandoned mines in Ticonderoga Township, none of which have been operated recently, as they have proved too uncertain, too pockety, and too small in extent to be minable under present conditions.

The graphite schists of the southern area, the commercial deposits of the Adirondacks, Alling divides into four groups in order of their relative economic importance, as follows:

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16 - Lee, W. T., Graphite Near Raton, N. Mex.: U. S. Geol. Survey, Bull. 530, 1913, pp. 371-374.

17 - Alling, H. L., The Adirondack Graphite Deposits: New York State Mus. Bull. 199, Albany, 1918.

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1. The normal quartz schist, carrying 5 to 7 per cent graphite, which comprises two beds in some properties and one bed in others and has an ore horizon of from 3 to 30 feet thick which tends to be micaceous both above and below. The mica content increases with increase in the feldspar content.

2. A feldspar-quartz schist, carrying 6 per cent graphite and 10 per cent micaceous minerals.

3. Another phase of the quartz schist, containing pyroxene and tourmaline in which the graphite has been redistributed so that certain layers are abnormally rich.

4. A meta-arkose, which consists almost entirely of potash feldspar, a specimen containing only 1.6 per cent graphite.

Only the material of the first group can be considered as graphite ore, but Alling estimates that the properties of Faxon, Hooper Bros., The Flake Graphite Co., and the Graphite Products Corporation, have a combined reserve of 10 to 13 million tons of graphite schist, one-half of which is readily available. Assuming that 3 per cent of the graphite is recoverable, these reserves should yield 3,000,000 pounds of graphite - enough to supply the normal requirements of the United States for this quality of graphite for 50 years.

North Carolina - Graphite is known to occur in many localities in the central and western parts of North Carolina, but attempts to work these deposits have generally failed. The principal deposits of the State have been briefly described by the North Carolina Geological Survey.[18]

A little flake graphite was shipped in 1911 from a deposit 4 miles north of Franklin. Some amorphous graphite was produced in 1916 in Catawba County. Early in 1919 a small quantity of crystalline graphite was mined near Shelby, N. C., by the General Graphite Co. of Birmingham, Ala.; this company also reported development work on South Carolina deposits.

Pennsylvania - Graphite has been mined intermittently in Pennsylvania from an early date. The principal producing deposits are situated about 30 miles west of Philadelphia, and occur in the gneiss of Pickering Valley, Chester County. With one exception the operations have been confined to soft, disintegrated material, analyzing 3½ to 4½ per cent graphitic carbon. The deposits usually dip 35 to 50° and have been mostly worked opencast, although there has been some underground mining employing room-and-pillar methods branching off from shafts or tunnels. The various operations have been described in some detail by F. Bascom.[19] In 1920, the Graphite Products Co., Beyers, Pa., reported a production from its mine at Uwchlan. Since then no production has been

18 - Pratt, J. H., The Mining Industry in North Carolina during 1901: North Carolina Geol. Survey Econ. Paper 6, 1902, pp. 69-72.

19 - U. S. Bureau of Mines, Mineral Resources of the United States, 1919: Pt. 2, pp. 318-322.

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reported from the Pennsylvania deposits, which apparently have all been idle.

Rhode Island - Graphitic shales have been worked in Rhode Island for many years. The deposits which occur in the vicinity of Providence and near Tiverton in Newport County represent a phase of the adjacent coal deposits. They were first developed successfully in 1889, but prior to 1898 none of the ventures appears to have been particularly profitable. The principal operation has been at Fenner Ledge, in Cranston, a suburb of Providence. This mine started as an open pit but has been continued underground. The material, which is associated with anthracite coal, is produced cheaply and is sold at a low price chiefly to foundry-facing manufacturers and paint grinders.

South Dakota - Amorphous graphite containing from 30 to 35 per cent carbon and about 40 per cent silica has been found in the Black Hills, notably about 1.4 miles (by wagon road) north of Oreville in Pennington County. Samples of this material seemed suitable for the production of paint pigments or foundry facings, but the distance from consuming centers represents an obstacle which apparently has not yet been surmounted.

Texas - In the central part of Texas, between Llano and Burnet, are situated deposits containing from 6 to 10 per cent graphitic carbon. The yield of No. 1 flake is rather small because amorphous graphite is present and because, as the gangue is hard, much flake is destroyed in grinding. The economic value of these deposits which occur in Packsaddle Mountain, a silicious pre-Cambrian formation intruded by granite pegmatite, is indicated by the fact that one company successfully continued operations after the war during a period when nearly all the other producers of crystalline graphite in the United States were idle. The principal producing company is the Southwestern Consolidated Graphite Co., a Boston concern (which has lately purchased another property, in Alabama). At the property of the Southwestern Graphite Co. the overburden, which varies in thickness from 2 to 8 feet, contains 3 to 4 per cent graphitic carbon. The graphite, however, occurs chiefly in large boulders contained in the hard-baked detritus along with considerable clay and vegetable matter. The ore-body is fully 100 feet thick and a mile long and it dips about 65 degrees southeast. It is mined by steam shovel and a wood-fired churn drill is used for drilling the holes preliminary to blasting. Five-ton motor trucks with automatic dump bodies are used for haulage to the mill, which now employs K-and-K flotation machines.[20]

Utah - During 1909 a mine was opened in Brigham in Box Elder County, Utah. In that vicinity there appears to be a fairly long belt of carbonaceous schists, forming part of an extensive series of altered sediments. The beds where exposed are 20 feet thick and appear to be persistent along the strike. An analysis made by the United States Geological Survey, however, showed no graphite, although the material contained an average of 3.48 per cent fixed carbon and selected samples showed 5.59 per cent. Apparently the material might be used for paint, although it has not yet been exploited on any substantial scale.

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20 - Menardi, H. B., "Modern flotation plant for graphite": Rock Products, vol. 31, No. 18, Sept. 1, 1928, pp. 74-7.

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Virginia - Graphite is known to occur in a number of localities in the Piedmont region, east of the Blue Ridge in Virginia.[21] Mention has been made in published reports of large exposure of graphitic schist at Somerset in Orange County (Somers Place) and also of specimens from Louisa County near Green Spring Depot, in Charlotte County on the road from Drakes Branch to Saxe, and in Powhatan County near Jefferson. Many years ago there was a graphite mine about 2 miles west of Buck Mountain in the northern part of Albemarle County. This mine was visited by Bastin in April, 1911, and was described by him in the chapter on graphite in Mineral Resources for 1913. The only visible exposure is on the south wall of an open pit where the rocks are much weathered. Here the pyroxene-syenite is cut by a single vein which varies from 1 to 2 inches across and branches off into the country rock in numerous short veins. The vein is composed largely of graphite which in places is earthy in texture, but in others is crystalline with a well-developed fibrous structure. The description of some hand specimens closely resembles that of Ceylon graphite. In 1915, a new shaft was sunk on this old property with encouraging results. In 1915, also, prospecting for graphite was carried on 3½ miles from Front Royal in Warren County. A sample examined by the United States Geological Survey consisted of schist containing graphite in minute flakes.

Washington - During the World War some development work was done on a graphite property on the east slope of the Cascade Range in Chelan County, several miles west of Nason Creek, Wash. Evidently there were opened up several bodies of schists containing a small percentage of graphite and occasional small veins or lenses up to 18 inches wide of richer material. The graphite particles are mostly under 0.5 millimeters in diameter. Although this graphite might be used for paint pigment, foundry facings, boiler-scale preventives, and possibly stove polish, it would be rather difficult to separate. Cost of milling and high freight constitute serious handicaps to the commercial utilization of these deposits.

Wisconsin - Amorphous graphite has been produced quite regularly in the vicinity of Junction City, Portage County, Wis. The product is crushed, dried, pulverized, and air-floated. In this condition it has been worth at times from $25 to $35 per ton. The carbon is said to range from 30 to 40 per cent. In both the principal properties the rock is a black slate or shale. The carbon is in such a very finely divided state that concentration is impracticable. It is uncertain whether the carbon is true graphite or merely amorphous carbon.

Wyoming - According to a bulletin by the State geologist[22] amorphous graphite is found in Laramie, Albany, Carbon, and Fremont Counties, the carbon content, as shown by analyses of samples, varying from 10 to 60 per cent. In Albany County there is a large district known as Plumbago Canyon, where there

21 - Watson, Thomas L., Mineral Resources of Virginia: 1907, pp. 188-190. Published by Jamestown Exposition Commission.

22 - Jamison, C. E., Mineral Resources of Wyoming: Wyoming State Geol. Bull. 1, ser. B, 1911, p. 34.

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are a great many deposits of graphite, and in Fremont County a deposit of graphite, said to be extensive and very pure, occurs near Miners Delight. Deposits in the Haystack Hills, Laramie County, occur in pre-Cambrian mica schist near its contact with granitic intrusive rocks. The largest band of graphitic schist observed has a thickness of only 8 to 10 feet, but can be traced along its strike for at least 1,000 feet. The richest material contains upward of 16 per cent of graphite, but the average probably would be from 6 to 8 per cent, and the flakes are very minute -- from 0.04 to 0.15 millimeters in diameter. The deposits were prospected as early as 1881, but have never been worked.[23]

FOREIGN DEPOSITS

Graphite is found in practically all parts of the world. Seven countries - Austria, Ceylon, Chosen, Czechoslovakia, Germany, Italy, and Madagascar furnish almost 85 per cent of the world output, but there are a dozen or more minor producing countries and innumerable localities where graphite, especially amorphous graphite, could be produced in quantity. Ceylon holds its place to a large extent because of the unique properties of its product, but elsewhere graphite mining is a matter of cost of production and transport to consuming market. The large output of Czechoslovakia, for example, is the result as well as the cause of a great local industry utilizing its products, and the same is true of Germany, Austria, and Italy. Districts such as Madagascar or Korea, remote from consuming centers, owe their exploitation solely to the fact that, due to favorable natural advantages and native labor, they can produce cheaply enough to overcome the handicap of having to ship their product halfway round the globe to market.

In the following notes no attempt is made to cover any but the more important present-day sources of world supply. Among the many localities which are not herein described, mention may be made at this point of Borrowdale (now exhausted) and other less famous places in England and Scotland; Berttula, Finland;[24] the Machakos District in Kenya (East Africa); the Victoria and Wankie Districts, Rhodesia; Uganda; Natal (near Ladysmith) and various other localities in British South Africa; Mt. Bopple, Queensland; Munglimup and Kendenup, Western Australia; Eyre's Peninsula, South Australia; Undercliffe, New South Wales; Senjen, Norway; the Departments of Suceara, Gorji, and Nehedinti, and the Carpathian Mountains, Rumania; Vittangi (amorphous) in Lapland and Norberg (flake) in central Sweden; Finland; Switzerland; the Belgian Congo and, just over the border therefrom, the Bambari District of French Equatorial Africa; Portuguese East Africa (Mozambique); Chile, Paraguay, and Uraguay; and Kirin, Shansi, and Honan (crystalline), and Chihli, Kiangsu, and Hunan (amorphous) in China.

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23 - Ball, S. H., Graphite in the Haystack Hills, Laramie County, Wyo.: U. S. Geol. Survey Bull. 315, 1907, pp. 426-28.

24 - Places noted in Finland, South Africa, Queensland, Australia, Rumania, Sweden, and China are described or mentioned by Imperial Mineral Resources Bureau. Graphite (1913-1919), London, 1923.

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NORTH AMERICA

Canada - Graphite is widely distributed through Canada, but the only deposits that have been worked extensively are in southern Quebec and Ontario. Nearly all the Canadian graphite is of the small-flake variety, although up to 1908 a considerable amount of amorphous graphite was produced near St. John, New Brunswick, and a few tons of crystalline vein graphite (cf. Ceylon plumbago) was mined in 1917-1918 from Baffin Island. The typical deposits are either in sillimanite gneiss or in crystalline limestone. A less common occurrence is of the contact metamorphic type. In many years over one-half the total Canadian output has been furnished by the Black Donald mine at Calabogie in Renfrew County. This is the largest graphite mine in the Western Hemisphere and perhaps in the world, and it has been worked almost continuously since 1896. After being destroyed by fire early in 1928, the mill and various mine buildings were rebuilt. At the time of the fire 200 men were employed. The deposit, which is contained in limestone, averages 65 per cent graphite, ranging from 40 to 80 per cent. The proportion of coarse flake to dust is about one to three, the percentage being larger, however, near the footwall. Formerly the product was all sold for foundry facings, practically as mined, but since 1909 it has been concentrated by flotation. Six grades are produced -- three for lubricating purposes and three for foundry facings and stove polish.

Although the Ontario deposits are in limestone, those in Quebec are all in gneiss, resembling the Adirondack deposits in New York; most of the Canadian deposits, however, contain larger percentages of graphite.

Artificial graphite has been produced in Canada by the Acheson Graphite Co., a subsidiary whose works are situated on both sides of the national boundary at Niagara Falls.

Most of the Canadian graphite is exported to the United States, but there is a small local consumption for crucibles, foundry facings, and pencils, all of which are manufactured in Canada.

Mexico - The largest graphite producer in North America is the United States Graphite Co. which produces amorphous graphite from extensive deposits situated a little south of Hermosillo, Sonora, about 350 miles from the American border at the Santa Maria mine. The main graphite bed averaged 9 to 10 feet in thickness, but being highly folded it pinched and swelled so that in places it reached a thickness of 24 feet. There are at least six beds of which two or three are of good quality and of mineable width. The beds, originally coal seams, occur in sandstone near a contact with the granite which sometimes appears on the walls, and in small dikes which cut the beds. The graphite is exceptionally pure, and selected samples contain as much as 95 per cent graphitic carbon. A typical analysis shows 86.75 graphitic carbon, 7.60 per cent silica, .65 per cent iron oxide, and 5.00 per cent alumina.[25] During the last few years new deposits have been mined which are even richer than the Santa

25 - Hess, F. L., "Graphite Mining near Colorado, Sonora, Mex.": Eng. Mag., vol. 38, 1909, pp. 36-48.

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Maria and are much more accessible to the railroad. The output is all shipped to the mill of the parent company in Saginaw, Mich., where it is reduced to impalpable powder and employed for pencils, powder glazing, electrotyping, foundry facings, lubricants, stove polish, graphite paint, etc. This graphite is said to be superior even to the best Austrian graphite for the manufacture of pencils.

Deposits have been opened up in the same general vicinity by other American interests but have furnished very little production. Graphite was first discovered in Sonora in 1863.

SOUTH AMERICA

Graphite has been mined in a small way in Chile, Paraguay, and Uraguay, and deposits on the island of Chiloé and in the province of Atacaoma in Chile are said to be of potential importance. So far, however, graphite mining on a commercial scale in South America has been practically confined to Brazil, which has exported small quantities to the United States.

Graphite schists containing 10 to 11 per cent carbon have been employed locally for pencil-making. In Minas Geraes, notably in the Lafayette district, abundant supplies both of flake and of vein graphite have been noted; undeveloped deposits of flake graphite have also been located in the State of Sao Paulo, and in a number of places in Bahia amorphous graphite has been observed.[26] Veins 19 to 40 inches thick containing masses of graphite weighing hundreds of pounds are reported to occur at Emparedado, Bahia, but lack of transportation has prevented development.[27] A deposit about 10 miles from Aracoiaba, a station on the Ceará-Baturité Railway about 50 miles from the port of Ceará may be opened up in a small way.[28]

EUROPE

Austria - The former Austro-Hungarian empire produced annually over one-third of the world's output of graphite. Although the tonnage was substantially greater than that of any other country, the value was low, as the material was almost exclusively amorphous and most of it of low grade. About two-thirds of the pre-war output was derived from deposits situated within the borders of the new State of Czechoslovakia, but there are important deposits in the Alps of Styria and in the hills of Lower Austria which remain within the present republic. In the Styrian Alps the graphite occurs in highly folded slates and limestone. The most important mines are at Kaisersberg and Trieben, where there are from three to seven seams ranging from a few feet up to 30 feet in thickness and extending more or less continuously for 30 miles. The Styrian graphite, since it is derived originally from coal seams, varies greatly in

26 - Ferguson, H.G., Mineral Resources of the United States, 1918: Pt. 2, 1918, p. 244.
27 - U.S. Department of Commerce Reports, 40a, Sept. 25, 1917, p. 16.
28 - U.S. Department of Commerce Reports, Nov. 26, 1928, p. 553.

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quality, some mines yielding soft earthy material and others a hard material grading into anthracite.

Graphite is produced in smaller amount in Lower Austria, where it is found in an area along the left bank of the Danube from 39 to 55 miles west of Vienna, probably an extension of the German district of Passau. Both crystalline and amorphous graphite have been mined. The former, however, is in very small flakes ("flinz"), rather sparsely disseminated in gneiss. Because the yield in flake is only 5 per cent and the flake is so small, this material is not mined under normal conditions, although during the war it was used for the manufacture of crucibles. Amorphous graphite occurs in graphitic slates which are found between the gneiss and mica schist. In the Muehldorf district a steeply dipping bed of impure graphite 35 to 130 feet thick occurs in crystalline limestone. As early as 1855 it had been mined to a depth of 500 feet in the Dunkelsteiner Wald. The graphite produced in Lower Austria, even after refining, contains only 60 per cent of carbon, but the rock is cheaply mined, and the yield is moderately high (30 to 50 per cent). The product is used principally for foundry facings but is also employed for electrical purposes and as a lubricant, more especially on the curves of street car tracks. In 1926 Lower Austria produced 4,500 tons of refined graphite; it could easily produce 7,000 tons. Of the two principal mines, the one situated at Muehldorf sells its own ore from an office in Vienna. The other at Horn sells through Heinrich Linn.

In Styria the crude ore runs from 40 to 95 per cent carbon, and needs only to be hand-sorted; some of it is shipped in lump form, but a considerable part of it is fine-ground and air-floated, and is then shipped in bags or wooden barrels. At the largest mine four grades are produced - one grade containing 45 to 65 per cent carbon; the next grade, 55 to 70 per cent; the next, 65 to 84 per cent; and the best grade, 82 to 84 per cent. The better grades are employed locally for making crucibles which although not so durable as those produced from crystalline graphite, are much cheaper. In 1926 the Styrian mines furnished 9,000 tons of crude graphite, but if the market permitted, they might yield four or five times this quantity. The principal mines are, in order of their recent production, the one of A. Miller's heirs at Treiben, Franz Mayr Melnhof's mine at Kaisersberg, and the Brockhues-Triebener graphite mine at Trieben - all owned apparently by one syndicate, Prager Handels Co., of Prague.[29]

Czechoslovakia - There are two graphite fields in Czechoslovakia, one in Bohemia and the other in Moravia. The former produces a little crystalline as well as amorphous graphite, while the latter produces only amorphous graphite. Although worked almost continuously since 1790 the mines of the Schwartzback-Krumau district in southern Bohemia, yield the bulk of the large output credited to that province, and there is said to be a large area of ground still undeveloped. The refined product resembles the graphite from Lower Austria in that it contains only 60 per cent carbon and is used chiefly for foundry facings and the cheaper kinds of pencils. The deposits are irregular lenses of graphite schist

29 - Petraschek, W., "Austrian graphite and its Sources": Eng. and Min. Jour., Oct. 8, 1927, p. 568.

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interbedded with other metamorphic rocks. The Kollowitz district yields a slightly better grade of graphite but in much less quantity, and the Smojanow district yields a poorer grade, containing much pyrite. The Moravian deposits lie mostly near the Bohemian boundary; the most important are those of Altstadt, Kunstadt, Mueglitz, and Oels, all in the Brunn (Brno) mining district.

> "In the Alstadt district beds of impure amorphous graphite underlie an area of about 4 square miles. In the Kunstadt district, beds of graphite-schist are mined. In the Müglitz district, a bed of graphite-schist containing 32 to 42 per cent carbon and ranging in thickness from 1½ to 65 feet, has been developed to a depth of over 300 feet. The graphite is used for manufacture of pencils and foundry facings. In the Oels district the graphite occurs in the same manner as at Müglitz, but the possible reserves are greater, and there are three beds 15, 18, and 35 feet thick, respectively. The graphite contains an appreciable amount of pyrite and is suitable only for pencils or paint."[30]

Germany - Although an important source of graphite, Germany has no surplus above its own large requirements. The imports in 1913 amounted to about three times the domestic output. This output is all derived from the Passau district in eastern Bavaria near the Austrian frontier. The economic value of these deposits is enhanced by the presence nearby of the famous Klingenberg clay, long considered the most suitable clay for crucibles. Crucibles were manufactured in Passau from local clay and graphite for the use of the alchemists in the Middle Ages. Before the war, Ceylon plumbago was used in large part even in Bavaria for making crucibles, and the local flake was employed principally for lubricants and foundry facings. In war time, however, Bavarian graphite was again used for crucibles, and the Passau district enlarged its output from 13,300 short tons of graphite in 1913 to 71,700 short tons in 1918.

The Bavarian graphite is of the disseminated flake type and occurs in lenses and pockets in gneiss and schist. Weathering extends to considerable depths; hence the ore is largely soft and sandy and is easily mined. Since the graphite content is fairly high, ranging from 20 to 30 per cent, production costs ought to be low.

France - Amorphous graphite has been mined in France for many years, chiefly in the Department of Hautes Alpes, close to the Italian border. The deposit is geologically similar to the Italian deposits. There are said to be undeveloped deposits also in the departments of Ariège and Rhone. Domestic supplies have been in the past, and will doubtless be in the future, a minor factor in the growing graphite-consuming industries of France.

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30 - Imperial Mineral Resources Bureau, Graphite, 1913-1919: London, 1923, p. 33.

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Italy - Amorphous graphite, grading in places into anthracite, occurs in beds up to 10 feet thick in the Provinces of Turin, Genoa and Cuneo in northern Italy. The best refined graphite averages 70 per cent carbon, and is suitable for foundry facings and lubricants. There is a considerable surplus above domestic needs, which are rather small. This surplus formerly went largely to Germany, but more recently it has been sent to France and England. A little was sent to the United States. Before the war the Italian graphite used to be very cheap and the ocean freight was only $2.50 per ton.

Spain - Spain began producing graphite in 1915 from deposits near Almonaster, in Huelva Province. The graphite is of the flake variety and occurs in enriched lenses containing 10 to 20 per cent graphite in a belt of graphitic schists which extends from Alojao to Aroche and possibly beyond the Portuguese frontier. They have been developed more or less for a distance of 10 miles along the strike and over a width in places of half a mile. From 1750 to 1800, a considerable output of crucible graphite was made in Malaga Province, but the deposit was apparently exhausted as this province has subsequently produced only intermittently and in a very small way. For many years before 1913 Spain's meagre requirements of crucibles and other graphite products were imported.

Russia - The graphite resources of Russia are thus described in Mineral Resources of the United States for 1918:

> "Russia, particularly Asiatic Russia, possesses large reserves of graphite, but, so far as data are available, the production has been insignificant. The famous Alibert mine, near Irkutsk in eastern Siberia, formerly produced a considerable quantity of pencil graphite, and this graphite has also been used to a small extent in the manufacture of crucibles. The other important deposits, those of Yenisei River in eastern Siberia and those in the northern part of the Caucasus Province, probably consist of amorphous graphite. Some work was done on the Yenisei deposits in 1908 and 1909. In the extreme eastern cape of Siberia there are graphite deposits similar to those of the Nome Peninsula, Alaska. The availability of the Russian deposits depends on the possible future development of Russia as a manufacturing country, for, unless the deposits should prove of exceptionally high grade, difficulties of transportation would reduce their availability for foreign use.
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> "At the outbreak of the war the Morgan Crucible Co. established a crucible factory in Russia, and a large quantity of Ceylon graphite was imported. It is not known whether the clay was also imported or whether suitable local supplies were obtained.
>
> "The only deposit in European Russia concerning which information is available is that of the Dzimarsk district, in the Caucasus. Here graphite, presumably amorphous,

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occurs in large beds or lenses with an average thickness of 1 meter and a known extension of 1,500 meters. The carbon content ranged from 30 to 60 per cent.

"Other occurrences are as follows:

"Pudosch district, near Onegasec, Olenetz government; Jelantschik district, southern Ural Mountains, granite boulders containing high-grade crystalline graphite; Zytomierc district, near Mecherzynce, Volhynia, near Mariupol, Jekaterinslav district, Ukraine, with a reported production of 2,000 tons (in 1913); Kumi Maggi, on the north shore of Ladoga Lake, Finland; Ekaterinburg; Miask; and Slatust. Graphite for foundry facings was recently mined at Boevsky, in the Ural Mountains."

Concessions have recently been offered by the Union of Socialist Soviet Republics for the exploitation of two graphite deposits, one in the Crimea and the other in the vicinity of Irkutsh in Western Siberia.

ASIA[31]

Ceylon - As measured by value of product, Ceylon has long been by far the principal graphite-producing locality. Competition from Madagascar combined with the curtailed demand for graphite crucibles for which Ceylon plumbago is particularly favored, has made heavy inroads into Ceylon's trade, but the island will continue for many years to be a large if not the principal source of world supply of high-grade graphite. The deposits were known as early as 1681; they were exploited before 1830 and have produced continuously since 1834. The increasing depth at which mining had been advanced has tended to increase costs, particularly in a country of such heavy rainfall, but reserves are still abundant and the graphite content of the rock is fairly high. The commercially important deposits, which lie in the Western and Southern Provinces, are all veinlike in character and were deposited along fracture planes in the rocks. Sometimes, however, the veins are so short as to be more correctly described as lenses. The width varies from less than one-eighth inch to several feet, and veins two-thirds of an inch wide or wider are said to be workable. In small veins the graphite usually forms an aggregate of platy needles set at right angles to the vein wall. In larger veins the graphite is ordinarily coarser though the needlelike structure may be developed for a short distance away from the walls. It is this needlelike material which when separated is classed as "needle lump," the highest priced of all Ceylon graphite because of its much desired fibrous structure. In addition to graphite, various gangue minerals may be present in the veins. Quartz and pyrite are nearly always present, and occasionally biotite, orthoclase-feldspar, pyroxene (usually augite), apatite, allanite, and rutile occur.

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31 - Siberian deposits are noted under European Russia.

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Graphite is mined either from open pits or through vertical shafts connected with underground workings. A few mines are as deep as 500 feet, but most of them are less than 100 feet deep. With few exceptions they are owned and operated by the native Sinhalese. As a rule the mining methods are still crude and modern equipment is conspicuously absent. The material as it comes from the pits may contain as much as 50 per cent of impurities, mostly in the form of quartz and wall rock. It is carried in bags to a dressing shed where the impurities are reduced to 5 or 10 per cent by hand picking, after which it is packed in barrels and shipped to Colombo or Galle. At these ports it is unpacked and given the final preparation for market. The methods of "curing" employed by the different merchants vary somewhat. Usually the large lumps are broken with small hatchets by women. This releases the coarser impurities and the smaller lumps of graphite can then be rubbed up by hand on a piece of wet burlap and polished. The lump and chip grades from different mines ordinarily differ somewhat in size or texture and must be blended to meet the demands of the trade, a process requiring skill and long experience. The refining of poorer material is done less carefully. After being beaten up by wooden implements it is sorted into different grades. Occasionally it is washed in a tub or pit, the material placed in saucer-shaped baskets, and the graphite thrown out in much the same way as fine sand is removed in panning gold. Very fine material is dried and thrown up into the air so that the graphite is winnowed out and falls on the floor.[32]

The United States, which has frequently consumed more than one-half of the total exports, has been the largest purchaser of Ceylon graphite; the balance has been taken principally by Germany and Great Britain. Before the war 30,000 tons or more were exported annually, and the business is said at times to have afforded employment to as many as 50,000 persons. Since the war, however, the Ceylon industry has been much depressed; exports have amounted to less than half and often scarcely more than one-third the pre-war shipments. Various plans have been proposed to get back at least some portion of the markets that have been lost to Madagascar, but the consensus is that the chief requisite is lower costs. One proposal is to form a Plumbago Exchange through which the small mines can get into direct touch with the exporter and thus eliminate the profits of two or three middlemen who now intervene in most transactions. There are 17 exporters of whom about half are Ceylonese and half are European firms.[33]

Chosen (Korea) - The graphite industry of Chosen dates only from about 1903 when the first exports were made, but by 1913 production had advanced to more than 16,000 short tons and consisted almost wholly of amorphous graphite. Deposits of crystalline graphite have been developed, and in fact a few shipments of Korean flake have been made to the United States, but production of this variety has been sporadic and the product of poor quality. The amorphous graphite occurs in beds and irregular lenses which are found mainly in the

32 - The deposits and methods of production in Ceylon are described in detail by Bastin in the chapter on Graphite in Mineral Resources of the United States, 1913, pt. 2, pp. 234-238.

33 - Mining Journal (London), "Ceylon graphite trade": Dec. 8, 1928, p. 1020.

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central and eastern parts of the country. In one district (Kyeng-Sang) there are three seams having maximum mineable widths of 78, 18, and 48 feet, respectively. The crystalline graphite occurs in the northern part of the country in thin flakes, resembling the Alabama deposits in the United States. Korean graphite is used largely in Japan which has a very small domestic production. It is also exported to other countries, including the United States. A considerable part of the export trade is transshipped at Japanese ports. American capital has been employed in the exploitation of these deposits.[34]

French Indo-China - The existence of graphite deposits in various localities of Indo-China has been known for years, but it was not until 1917 that commercial exploitation began. The earlier work was down in Annam but veins were later opened up in Upper Tonkin on the banks of the Tam-Ty River near the Yunnan frontier. The ore as mined contains about 20 per cent carbon and the flake produced is said to be low in iron, almost free from sulphur, and otherwise suitable for crucibles, pencils, lubricants and other articles. The graphite occurs at the surface and is easily mined. A concentrating plant has been installed at the mine, and the output, all from one company, may be increased shortly to 4,000 tons annually. A little ore is being shipped to England and Germany and a few sales have been made direct to the United States but the bulk of the material is exported to France whence it may be reexported either crude or after treatment in a refining plant. Quotations c.i.f. French ports are approximately 2,300 francs (about $90) per metric ton for the 86 per cent carbon product.[35]

Exports were 8,000 metric tons in 1917, and were increased to 15,000 metric tons in the following year. This material came from Annam and much of it contained only 44 per cent graphite, although it doubtless could have been brought up to 80 per cent by more careful mining and sorting. In 1920 the industry collapsed and no exports were made from Indo-China for several years until in 1924 2,264 metric tons were exported. Later mining activity declined once more until the new deposits in Tonkin were opened up.

India - The State of Travancore in southern India formerly produced graphite similar to the Ceylon material; however, production became unprofitable with increasing depth, and there has been little or no output since 1913. A small amount has come from the State of Rajputana in the central part of the peninsula.

Japan - Japan produces a certain amount of graphite but not enough to supply the local market which depends partly on imports from Korea, Ceylon, etc. From 1900 to 1909 the output comprising both crystalline and amorphous grades fluctuated from 195,000 to 480,000 pounds. The occurrences are mostly in bedlike deposits, although there are a few veins. Of the bedlike deposits

34 - U. S. Bureau of Mines, Mineral Resources, 1919: Pt. 2, pp. 199-200.
35 - Data furnished by E. A. Masuret, Office of U. S. Trade Commissioner at Paris. (Trade Notes No. 227.)

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two varieties are noted:(1) flake deposits in Archean gneiss and (2) masses of amorphous graphite in Palaeozoic slates and Mesozoic shales. The flake deposits, which furnish the bulk of the production, are situated in the Provinces of Hida and Etchu in central Nippon. The deposits of amorphous graphite are found in the Provinces of Rikuzen in northern Nippon, and in Nagato and Satsuma in the southern part of the island. Graphite from Kataya in the Province of Kaga in central Nippon, said to occur as a vein deposit, is of high quality; it is used for pencil manufacture.[36]

AFRICA

Madagascar - Although the presence of graphite in Madagascar had been noted as early as 1838 the graphite industry of this French colony dates only from 1907 when 8 metric tons were produced and there was no appreciable exportation until 1911. By 1913, however, the annual output had grown to 8,000 metric tons and in 1917 it reached 35,000 tons. The graphite is of the flake variety and is similar in appearance to the best American flake although somewhat thicker. The occurrence is widespread throughout the graphitic schists and gneiss which comprise over two-thirds of the surface of the island. The ore lies in seams like coal, striking north and south with a general dip to the west. The beds are many miles in length and of considerable thickness - usually 30 to 65 feet and sometimes more. At operating mines the overburden never exceeds 6 to 10 feet. Mica appears principally in the upper portions and thus may be discarded in mining. The workable beds consist mainly of graphite and quartz and are so soft and decomposed that they can be dug out with wooden spades. The graphite content probably averages from 10 to 12 per cent. In the plateau region material containing 7 per cent of graphite is classed as ore, but in the coastal plain where transportation is better and there is more water for washing, the workable limit is 5 per cent.[37] On the other hand at one mine the graphite content is 40 per cent, and in some cases it is reported to be 50 or 80 per cent. In addition to flake graphite there is said to be more or less lump or fibrous graphite resembling that produced in Ceylon, but it has not yet appeared in any substantial quantity in the exports.

The deposits are usually worked by open cuts, although in a few cases they are opened up by short tunnels. Various crude processes are employed for raising the grade of the mine product. Sometimes the ore will be dumped into a mud box 3 feet square by 2 feet deep where it is spaded over in a stream of water. The overflow from this box -- suspended sand, mud, and flake graphite -- is passed over a 60-mesh screen. The flake remains on the screen and is gradually worked forward into a small box. In another cleaning process the mine dirt is beaten with a mallet or club, thrown into a square tub, and then agitated constantly; the graphite remains in the tub with the sand from which, after drying in the sun, it is separated by screening. In 1927 a concentrating plant

36 - Mining in Japan, past and present, Bureau of Mines. Japan, 1909, pp. 133-5 (digested by Bastin, E. C., in Mineral Resources of the United States, pt. 2, 1909, p. 27).

37 - Lavila, L., Graphite: First Commercial Fair (pamphlet), Tananarive, 1923.

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was placed in operation by Lasnier & Co. at Tananarive.[38] Machinery for this plant was supplied by the Humboldt Co. of Cologne, Germany. The crude ore is ground in a ball mill, apparently in closed circuit with a classifier, and then treated in a 12-cell mineral separation flotation machine, the concentrates being filtered. The tailing was said to run 1 or 1½ per cent carbon, and from 8/10 to 1 ton per hour of 87 to 88 per cent concentrate is obtained from crude material containing 40 per cent carbon. With richer ore a 90 per cent product can be made.

The leading factor in the Madagascar industry is the Maskar Co. which has a large warehouse at Tamatave and buys its ore from the many native operators. It is a subsidiary of the Morgan Crucible Co. of London, England, although in compliance with French law it is registered as a French company and has a French manager.

Formerly Madagascar graphite varied in quality from very good to rather poor, but under the auspices of the French Government a standard of 85 per cent was established, and material corresponding to this standard may be certified by an official stamp affixed to a lead seal. As early as 1922 a graphite commission was set up by the Governor General for the purpose of furthering the use of Madagascar graphite, and extensive advertising was done in the United States and Germany.

Madagascar has enormous reserves of readily available graphite of good quality. Costs of production some years ago were estimated at 450 francs, but in some instances they were as low as 250 francs per ton. In 1925 T. G. Hunter, a representative of the Ceylon Government, estimated the average as between 600 and 1,000 francs, and subsequently somewhat higher averages have probably been maintained. The labor shortage which has been a factor limiting production in peak periods doubtless could be remedied by introducing modern methods of mining and refining and even a small amount of modern equipment. Certain of the larger French consolidations have recently made some progress in this direction. In 1917 the graphite industry gave employment to several thousand white men and about 200,000 natives, but subsequently mining has had to compete with the growing of vanilla, maize, coffee, and other remunerative agricultural products. As in many native communities, larger wages, instead of attracting more labor, result simply in a reduction of the number of days worked. The average output of graphite per man per day is about 1 ton and the average wages are about 3 francs per day. Royalties vary; in one case reported by Mr. Hunter the royalty was about 100 francs per ton.[39]

Aside from labor conditions transportation is the principal handicap of the Madagascar industry. There are few roads on the island, and even when a new road is constructed it can scarcely be maintained except at prohibitive cost; often the product has to be carried to the warehouses on the backs of natives.

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38 - Madagascar refinery at Tananarive: Bull. Econ. Mens. No. 12 (Tananarive), Nov., 1927, pp. 44-46.

39 - Report of Plumbago Industry Committee, Colombo, XXXI: 1925 (Government Record Office), 15 pp.

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Many of the mines, however, are within fairly easy reach of railroad or canal. Two men in a canoe, costing about 400 francs, can carry 3 tons so that even though the round trip lasts two or three days the carriage to railroad is often fairly cheap. From Tananarive to Tamatave the distance is 225 miles and the freight rate varies from 42.50 francs (about $1.65) per metric ton in carload lots (20 tons) to 50 francs per ton for shipments of less than 10 tons. Even after it reaches the warehouses at Tamatave, however, Madagascar graphite must be shipped a great distance before it reaches the markets of Europe or the United States. Except for an occasional shipment from Vatomandry -- somewhat further south -- Madagascar graphite is all shipped from the Port of Tamatave. According to Mr. Hunter carriage to French ports, both Havre and Marseilles, is by way of Messageries Maritimes and Havre Lines; the freight in 1925 was 165 francs or about $8 per metric ton. The ocean freight to London was 45 shillings ($11) and to New York 65 shillings ($15.85) per gross ton -- all in English bottoms. In 1925 the rate quoted to New York was $17.90 per gross ton.

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